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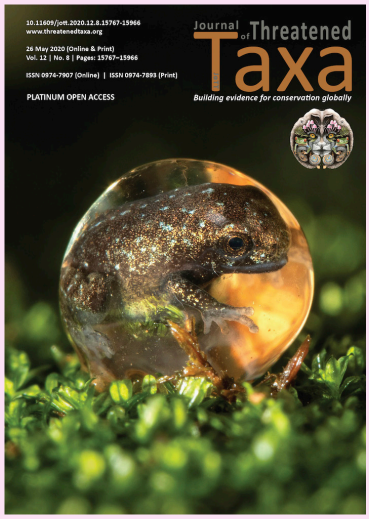

COMMUNICATION

COLLECTING PARASITIC ACULEATA (HYMENOPTERA) FROM RICE ECOSYSTEMS OF TAMIL NADU, INDIA

J. Alfred Daniel & K. Ramaraju

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COMMUNICATION

Collecting parasitic Aculeata (Hymenoptera) from rice ecosystems of Tamil Nadu, India

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Abstract: Surveys were conducted to explore the parasitic aculeate fauna in rice ecosystems of Tamil Nadu in 2015–2016 in three different rice growing zones, viz., the western zone, the Cauvery delta zone and the high rainfall zone. The study recorded a total of 32 aculeates that represent 12 species under seven families belonging to three super families, viz., Apoidea (Apidae), Chrysidoidea (Bethylidae, Chrysididae, & Dryinidae), and Vespoidea (Mutillidae, Scoliidae, & Thiphiidae). Alpha and beta diversity were computed for the three zones and the diversity indices (Simpson's index, Shannon-Wiener index, Pielou's index) revealed the high rainfall zone as the most diverse zone, with the Cauvery delta zone being the least diverse. On comparing the species similarities using the Jaccard's index in between the three zones taken in pairs, it was found that 42 per cent similarity existed between the western and Cauvery delta zone and 11 per cent similarity between high rainfall and Cauvery delta zones and 16 per cent similarity between the high rainfall and western zones.

Keywords: Apidae, Bethylidae, Chrysididae, diversity, Dryinidae, indices, Mutillidae, Scoliidae, Tiphiidae.

ஆய்வுச்சுருக்கம்: தமிழ் நாட்டில் 2015 ஆம் ஆண்டு ஆகஸ்ட் மாதம் முதல் 2016 ஆம் ஆண்டு ஜனவரி மாதம் வரை ஒட்டுண்ணி அக்கியுலேட்டாக்களுக்கான கணக்கெடுப்பு மூன்று மண்டலங்களில் நடத்தப்பட்டது, அவையாவன மேற்கு மண்டலம், காவேரி டெல்டா மண்டலம் மற்றும் மழைமிகு மண்டலம். இந்த கணக்கெடுப்பின் மூலம் மொத்தம் 32 அக்கியுலேட்டா ஒட்டுண்ணிகள் அகப்பட்டன. இவற்றுள் 12 இனங்கள் அடங்கும். இந்த 12 இனங்கள் மூன்று பெருங்குடும்பங்களின் (ஏப்பாய்டியா, கிரைஸிடாய்டியா மற்றும் வெஸ்பாய்டியா) கீழ் உள்ள 7 குடும்பங்களின் கீழ் வகைப்படுத்தப்பட்டுள்ளது அவையாவன ஏப்பிடே, பெத்திலிடே, கிரைஸிடிடே, டிரைனிடே, மியூட்டிலிடே, ஸ்கோலிடே மற்றும் திப்பிடே. ஜெக்கா்டு குறியிடைக் கொண்டு மண்டலங்களுக் கிடையிலான ஒப்புமைத் தன்மையை கணக்கிட்டபோது 42 சதவீத ஒப்புமை மேற்கு மற்றும் காவேரி டெல்டா மண்டலங்களுக்கிடையில் இருப்பது கண்டறியப்பட்டது. மழைமிகு மண்டலம் மற்றும் காவேரி டெல்டா மண்டலங்களுக்கிடையில்11 சதவீத ஒப்புமையும் 16 சதவீத ஒப்புமை மழைமிகு மற்றும் மேற்கு மண்டலங்களுக் கிடையிலும் இருப்பது கண்டறியப்பட்டது. பன்முகத்தன்மை குறியீடுகளான சிம்ப்ஸன்ஸ், ஷெனான் மற்றும் மாா்கலெப் குறியீடுகள் கணக்கிடப்பட்டு மழைமிகு மண்டலத்திலேயே அதிக பல்லுயிா் பெருக்கம் இருப்பதாக கண்டறியப்பட்டது. மிக குறைந்த பல்லுயிா் பெருக்கம் காவேரி டெல்டா மண்டலத்தில் இருப்பதாக தெரியப்பட்டது.

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Author contribution: JAD involved in the collection of insects, segregation of collected insects up to family level, performed statistical analysis, and wrote the manuscript. KR involved in correction of the manuscript and he is the advisor of the whole study.

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Ministry of Minority Affairs
ज्ञान-विज्ञान विमुक्तये

INTRODUCTION

Rice fields have unique characteristics that make them ideal grounds for diverse biological organisms. In addition, the different growth stages of the rice plant from seedling to harvest create micro-climatic conditions, offering a variety of habitats and niches conducive to a variety of life forms (Edirisinghe & Bambaradeniya 2010). Thus, it is an ecosystem which sustains not only the people whose staple diet is rice but also a diverse assemblage of plants and animals that have made rice fields their niche. But indiscriminate use of insecticides in rice fields has resulted in the loss of biodiversity of beneficial organisms like hymenopteran insects (Dudley et al. 2005).

Reducing the mortality of hymenopterans caused by insecticides is essential for greater sustainability in rice pest management (Heong & Hardy 2009; Gurr et al. 2011). They show greater stability to the ecosystem than any group of natural enemies of insect pests because they are capable of living and interacting at a lower host population level. A typical phytophagous insect is host to about five species of Hymenoptera (Hawkins 1993). Destroying one parasitoid species, therefore, may have unpredictable and immeasurable effects on the abundance of a number of phytophagous insects (LaSalle 2003). These studies suggest how important hymenopterans are in their natural habitats.

Although the species composition of terrestrial insects in rice fields throughout the world is relatively well documented, only a few studies have examined the biodiversity of hymenopterans in rice fields (Heckman 1974, 1979). The studies regarding the ability of aculeate Hymenoptera to utilize wetlands is far from satisfying (Stapenkova et al. 2017). Aculeata is one of the largest groups of insects and a few of them are parasitoids attacking a wide range of insects in their various stages of development, thereby playing a pivotal role in ecological balance. The diversity of parasitic aculeates associated with rice ecosystem is poorly studied in Tamil Nadu, hence the present study was undertaken.

MATERIALS AND METHODS

Sites of collection

The survey was carried out in the rice fields in 2015–2016 in three different agroclimatic zones of Tamil Nadu State, viz.: western zone (District representation: Coimbatore at Paddy Breeding Station, Coimbatore, 427m, 11.007N, 76.937E), Cauvery delta zone (District representation: Thiruvarur at Krishi Vigyan Kendra, Needamangalam, 26m, 10.774N, 79.412E), and high rainfall zone (District representation: Kanyakumari at Agricultural Research Station, Thirupathisaram, 17m, 8.207N, 77.445E). Collections were made for 20 consecutive days in each zone to give equal weightage and to minimize chances of variations in the collection. The time of sampling in each zone was decided based on the rice growing season of the zone and the stage of the crop, i.e., 20 days from August–September 2015 in the western zone, October– November 2015 in the high rainfall zone, and December 2015–January 2016, in the Cauvery delta zone.

Methods of collection

A total of three different gadgets, viz., sweep net, yellow pan trap kept at ground level, and yellow pan trap erected at canopy levels were employed. All the three gadgets were employed continuously for 20 days.

Preservation and identification of the specimens

The parasitoids, thus, collected were preserved in 70% ethyl alcohol. The dried specimens were mounted on pointed triangular cards and studied under a Stemi (Zeiss) 2000-C and photographed under Leica M205A stereozoom microscopes and identified through conventional taxonomic techniques by following standard keys. For future references all the identified specimens were submitted at Insect Biosystematics Laboratory, Tamil Nadu Agricultural University, Coimbatore. Species identity was made by following standard keys and also by confirming them with concerned experts from various institutes like, Lynn S. Kimsey, professor of entomology, UC Davis Department of Entomology and Nematology for Chrysididae and Tiphiidae, Arkady S. Lelej, entomology professor, Russian Entomological Society for Mutillidae, and Manickavasagam of Annamalai University for Dryinidae.

Measurement of diversity

Relative density (calculated by the formula, Relative Density (%) = (Number of individuals of one species / Number of individuals of all species) X 100, alpha diversity, viz., Simpson's index (Simpson 1949), (SDI is calculated using the formula $D = \Sigma n\ (n-1)/\ N(N-1)$ where n=total number of organisms of a particular species and N=total number of organisms of all species. Subtracting the value of Simpson's index from 1, gives Simpson's Index of Diversity (SID). The value of the index ranges from 0 to 1, the greater the value the greater the sample diversity). Shannon-index (Shannon, 1948), Margalef richness index (Margalef 1958), Pielou's evenness index (Pielou 1966; Magurran 1988), and beta diversity using Jaccard index (Jaccard 1912) were calculated using the online software Biodiversity Calculator (https://www.alyoung.com/labs/biodiversity_calculator.html).

Statistical analysis

The statistical test ANOVA was also used to check whether there was any significant difference in the collections from three zones. The data on population number were transformed into X+0.5 square root before statistical analysis. The mean individuals caught from three different zones were analyzed by adopting randomized block design (RBD) to find least significant difference (LSD). Critical difference (CD) values were calculated at five per cent probability level. All these statistical analyses were done using Microsoft Excel 2016 version and Agres software version 3.01.

RESULTS AND DISCUSSION

Parasitic Aculeata

In the present study, a total of 32 aculeates were collected from rice ecosystems that represent 12 species under seven families (Images 1–12), viz., Apidae, Bethylidae, Chrysididae, Dryinidae, Mutillidae, Scoliidae, and Tiphiidae.

Parasitic aculeate faunal surveys of rice ecosystems in western Cauvery delta and high rainfall zones of Tamil Nadu revealed that the species richness was maximum (7) in both western and high rainfall zones. Abundance wise, the high rainfall zone stood first with a total collection of 14 individuals. The western zone ranks second with a total collection of nine individuals and Cauvery delta region represented the least abundant with a total collection of seven individuals.

The Simpson's index of diversity is highest for high rainfall zone (0.91) and lowest for western zone (0.87) (Table 2), revealing more diversity in high rainfall zone than the western zone. A similar trend was observed for the Shannon index also. From the values of Margalef richness index for the three zones, it was found that the high rainfall zone was very rich in species with a richness value of 3.03 followed by western zone (2.08), while for Cauvery delta zone the value is 2.05. The Pielou's evenness value for the sites clearly indicated that the evenness patterns of all the three zones were almost the same with evenness index value 0.41 for Cauvery delta zone, followed by western zone (0.40) and high rainfall zone (0.40) (Table 2). The species composition among elevational zones can indicate how community structure changes with biotic and abiotic environmental pressures (Shmida & Wilson 1985; Condit et al. 2002). Studies on the effect of elevation on species diversity of taxa such as spiders (Sebastian et al. 2005), moths (Axmacher & Fiedler 2008), paper wasps (Kumar et al. 2008), and ants (Smith et al. 2014) reported that species diversity decreased with an increase in altitude, however, according to Janzen (1976), diversity of parasitic Hymenoptera is not as proportionately reduced by elevation as in other insect groups, a fact that is in support of our results.

A similar study conducted by Shweta & Rajmohana (2016) to assess the diversity of members belonging to the subfamily Scelioninae also declared that the elevation did not have any major effect on the overall diversity patterns. Daniel et al. (2017) obtained similar results by conducting experiments to assess the diversity of pteromalids of rice ecosystems in Tamil Nadu. The elevation dealt with in that work ranged from 17–427 m which was not very high. So taking into account the scale and extent of elevational gradients, it can be said that species diversity and richness have not showed any correlation, i.e., species diversity and richness were not proportional with that of elevation.

On comparing the species similarities using the Jaccard's index in between the three sites taken in pairs, it is found that 42 percent similarity between western zone and Cauvery delta zone and 11 per cent similarity between high rainfall zone and Cauvery delta zone. The similarity between western zone and high rainfall zone is 16 per cent. All the parasitic aculeates that were collected along with their host details were presented in Table 3.

Apidae

Under the family Apidae, only one species, *Thyreus ceylonicus* (Friese) was collected only from the western zone. Since, only one species was caught, diversity indices cannot be calculated.

The bee genus *Thyreus* Panzer is cleptoparasitic on species of *Amegilla* Friese possibly on *Anthophora* Latreille and *Eucera* Scopoli (Stoeckhert 1954). Matsumura et al. (2004) have collected a few kleptoparasitic cuckoo bees from the rice fields of Japan.

Bethylidae

Two species of bethylids, viz., *Goniozus indicus* (Ashmead) and *Holepyris hawaiiensis* were collected in the present study. Though *G. indicus* was found to be common to all the three zones, *H. hawaiiensis* was

Images 1–12. Twelve species of parasitic Aculeata collected from three rice growing zones of Tamil Nadu. 1—*Thyreus ceylonicus* (Friese) | 2—*Goniozus indicus* (Ashmead) | 3—*Holepyris hawaiiensis* (Ashmead) | 4—*Stilbum cyanarum* (Forster) | 6—*Dryinus* sp. | 6—*Gonatopus* sp. | 7—*Haplogonatopus* sp. | 8—*Storozhenkotilla* sp. | 9—*Zavatilla* sp. | 10—*Campsomeriella collaris* Betrem | 11—*Scolia affinis* Guerin | 12 —*Mesa* sp. © Alfred Daniel, J.

Table 1. Comparison of parasitic Aculeata collected from three rice growing zones of Tamil Nadu.

Species	Zones						Total			
	Western		Cauvery Delta		High Rainfall					
	No.	%	No.	%	No.	%	No.	%	F	P
Apidae *Thyreus ceylonicus*	1	100	0	0.0	0	0.00	1	100	1.00	0.37
Bethylidae *Goniozus indicus*	3	75	2	100	7	100	12	92.3	1.33	0.27
Holepyris hawaiiensis	1	25	0	0	0	0	01	7.7	1.00	0.37
Chrysididae *Stilbum cyanarum*	0	0.0	0	0.0	1	100	1	100	1.00	0.37
Dryinidae *Dryinus* sp.	1	50	2	40.0	0	0	3	37.5	1.03	0.36
Gonatopus sp.	1	50	3	60.0	0	0	4	50.0	1.20	0.30
Haplogonatopus sp.	0	0	0	0	1	100	1	12.5	1.00	0.37
Mutillidae *Storozhenkotilla* sp.	0	0.0	0	0.0	1	33.3	1	33.3	1.00	0.37
Zavatilla sp.	0	0	0	0	2	66.7	2	66.7	1.00	0.37
Scoliidae *Campsomeriella collaris*	1	100	0	0	1	50	2	66.7	0.5	0.60
Scolia affinis	0	0	0	0	1	50	1	33.3	1.00	0.37
Tiphiidae *Mesa* sp.	3	100	0	0.0	0	100	3	100	1.00	0.37
Total collected	**11**	-	**07**	-	**14**	-	**32**	-	-	
Number of species	**07**	-	**03**	-	**07**	-	**12**	-		

%- Relative Density, No.- Total number of individuals collected, F-Value, P-Value

found only in the western zone. Among the three zones, high rainfall zone (7) was found to have more number of bethylids followed by western zone (4) and Cauvery delta zone (2) (Table 1). A total of 13 numbers of bethylid individuals were collected from all the three zones.

A mean of 0.20 ± 0.12 bethylids were collected per day from western zone. Cauvery delta zone and high rainfall zone yielded 0.10 ± 0.07 and 0.35 ± 0.15 bethylids per day, respectively.

Chrysididae

Under the family Chrysididae, only one species, *Stilbum cyanarum* (Forster) was collected in the present study. *Stilbum cyanarum* was collected from high rainfall zone alone. Since only one species was caught, diversity indices could not be calculated.

Dryinidae

In the present study, a total of eight dryinid individuals comprising three different species, viz., *Dryinus* sp., *Gonatopus* sp. and *Haplogonatopus* sp. were collected. *Dryinus* sp. and *Gonatopus* sp. were common to both western zone and Cauvery delta zone, but *Haplogonatopus* sp. was obtained only from the high rainfall zone. It was found that the Cauvery delta zone was the most dryinid abundant zone with a total collection of five numbers followed by western zone (2) and high rainfall zone represented by only one individual

Mutillidae

Two species, *Storozhenkotilla* sp. and *Zavatilla* sp., were collected under the family Mutillidae. Both the species were collected from the high rainfall zone alone. A total of three mutillid individuals were collected in the present study (Table 1).

High rainfall zone recorded a mean of 0.15 ± 0.11 individuals per day. Since, mutillids were collected only from high rainfall zone no comparison between zones were made. Heong et al. (1991), Bambaradeniya et al. (2004), and Samin et al. (2011) have recorded mutillids from the rice fields of Philippines, Sri Lanka, and Iran, respectively.

Scoliidae

Two species, *Campsomeriella collaris* Betrem and *Scolia affinis* Guerin, were collected in the current study. Though *C. collaris* was obtained both from the western and high rainfall zones, *S. affinis* was obtained only from high rainfall zone. No scoliids was caught from Cauvery delta zone.

Table 2. Diversity indices of parasitic Aculeata from three rice growing zones of Tamil Nadu.

Zones	Mean number of all aculeates collected/day	SE	SID	*H'*	a	*E1*	b %
Western	0.55 (0.94)	± 0.22	0.87	0.72	2.08	0.40	W and C – 42
Cauvery Delta	0.35 (0.87)	± 0.15	0.90	0.67	2.05	0.41	C and H - 11
High Rainfall	0.70 (1.02)	± 0.23	0.91	0.88	3.03	0.40	H and W - 16
S.ED	0.10	-	-	-	-	-	
CD (p=0.05)	0.20	-	-	-	-	-	

Figures in parentheses are square root transformed values; In a column, means followed by a common letter(s) are not significantly different by LSD (p=0.05) | SID—Simpson's Index of Diversity | *H'*—Shannon Index | a—Margalef index | *E1*—Pielou's index | b—Beta diversity (Jaccard Index) | W—Western Zone | C—Cauvery Delta Zone | H—High Rainfall Zone | S.ED—Standard Deviation | CD—Critical Difference | SE—Standard Error (same table third column).

Table 3. Parasitic aculeates collected in the study along with their host.

Parasitoid	Host	Reference
Thyreus ceylonicus	*Amegilla* sp. & *Anthophora* sp.	Lieftinck, 1962
Goniozus indicus	*Cnaphalocrocis medinalis* *Scirpophaga* sp.	Gifford, 1965
Holepyris hawaiiensis	*Corcyra cephalonica*, & *Plodia interpunctella*	Amante et al. 2018
Stilbum cyanarum	Eumenidae, Sphecidae, & Megachilidae	Tormos et al. 2006
Dryinus sp.	Plant hoppers	Guglielmino et al. 2013
Gonatopus sp.	Plant hoppers	Guglielmino et al. 2013
Haplogonatopus sp.	Plant hoppers	Guglielmino et al. 2013
Storozhenkotilla sp.	Coleoptera, Diptera, & Hymenoptera	Lelej et al. 2007
Zavatilla sp.	Coleoptera, Diptera, & Hymenoptera	Lelej et al. 2007
Campsomeriella collaris	Scarabaeoidea	Vidyasagar & Bhat 1991
Scolia affinis	Scarabaeoidea	Vidyasagar & Bhat 1991
Mesa sp.	Scarabaeoidea	Vidyasagar & Bhat 1991

A mean of 0.05 ± 0.05 and 0.10 ± 0.10 scoliids were collected per day from western zone and high rainfall zone, respectively. Since only one species was recorded from western zone and no species were recorded from Cauvery delta zone, diversity indices could not be calculated for these two zones

Tiphiidae

Under the family Tiphiidae, three individuals of *Mesa* sp. were collected from western zone. The other two zones have not accounted for Tiphiidae. These are parasitoids of subterranean beetle larvae, especially of Scarabaeoidea and Tenebrionidae occurring in soil or rotten wood; some are found to parasitize mole crickets (Allen 1996). Heong et al. (1991), Bambaradeniya et al. (2004), and Fritz et al. (2011) have collected Tiphiidae from rice ecosystem of Philippines and Sri Lanka.

CONCLUSION

This study reveals the diversity of parasitic Aculeata of three different rice ecosystems of Tamil Nadu, where the high rainfall zone is the most diverse and the Cauvery delta zone being the least. The reasons for the significant changes in diversity of aculeates and their host insects are to be further studied.

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